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Construction and Evaluation of the LANL Prototype Compton Gamma-Ray Imager

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Abstract:

Compton imaging, which reconstructs the direction of incident photons based on the kinematics of Compton scattering, is of interest in the fields of astrophysics, medical imaging, and nuclear nonproliferation. To explore the capabilities of this approach for detecting and imaging spatially extended radiation sources at relatively close distances, we are developing a prototype system using commercially available detector technologies. In the LANL prototype system the Compton scatter takes place in one of three layers of thin silicon pixel detectors and the secondary photon is measured in an array of CsI(Tl)/PIN diode detectors. Construction of the prototype is about to be completed. In this paper we will present preliminary results from the prototype device along with computer simulations of the expected performance. In the future, these data will be used to explore design options for large operational Compton imaging systems.

Summary:

The Compton gamma-ray imaging technique uses the physics of Compton scattering to reconstruct the directions and energies of incident photons. It is of greatest interest for detecting radioactive nuclear materials with enhanced sensitivity compared to current methods. Applications being pursued include astrophysics, medical imaging, and nuclear nonproliferation. In the latter case, Compton imaging offers promising capability for detecting the weak gamma-ray emissions from concealed special nuclear materials (SNM). With this technique it should not only be possible detect a hidden or shielded SNM, but also locate it within an obscuring object, measure its size, and in some cases identify the intervening attenuators via (n, gamma) interactions with the attenuators.

To study the capabilities of a Compton imager for SNM detection in the laboratory setting, we are constructing a prototype system with currently available detection technologies. In the LANL prototype imager the Compton scatter takes place in one of three layers of thin silicon pixel detectors and the secondary photon is measured in an array of CsI(Tl)/PIN diode detectors. We have procured and evaluated both detector systems, along with custom integrated electronics, data acquisition, and associated software. The integrated system is about to be completed. We expect to perform preliminary performance measurements this summer, and report the results in this paper.

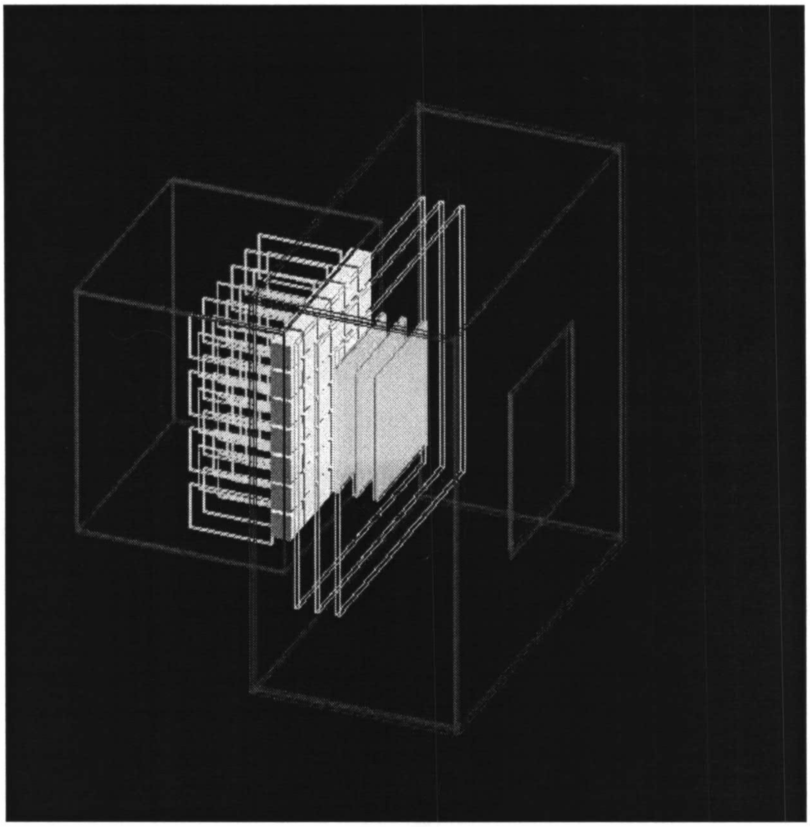

Fig. 1. Simulation model geometry of the prototype Compton imager showing three silicon detectors, scintillator array, support structure, and electronics boards. Large box is approximately 20 x 20 cm^2.

In parallel with the hardware effort, we have completed GEANT3 and GEANT4 Monte Carlo simulation models of the prototype system (Figure 1). These models are being used to (1) optimize the geometry of the prototype imager, (2) develop data selection criteria for efficient operation, and (3) develop imaging analysis algorithms. The algorithms will be adapted for use on experimental data when they become available. We expect to be able to report direct comparisons of imaging results between simulations and experiment.